

PSA'S VIEWS ON COMPATIBILITY : A POTENTIAL TWO-STEP APPROACH TO IMPROVE COMPATIBILITY AMONG THE VEHICLE FLEET

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ABSTRACT

Up to now, self-protection was the main item car manufacturers focused on for passive safety. But the improvements have led to more aggressive vehicles in car to car impacts, and phenomena that happen in these crashes are not well understood.

However it seems that good interaction is a prerequisite, otherwise cars have to cope with loads they have not been designed for.

PSA's proposal is to achieve car compatibility in two steps.

The first step consists in dealing with the most important problems:

- Improve geometrical compatibility with a test in which the vehicle has to use the connections between its load paths in order to create a good interaction surface with the barrier.
- Improve compartment stiffness - we are sure it will reduce the risks of being crushed in case of incompatibility - by imposing a minimum compartment resistance.

Front-end stiffness and energy absorption could then be put under control in a second step when we have a better knowledge of compatibility, and depending on the improvements obtained with the first step.

INTRODUCTION

The introduction of offset frontal crash tests in European regulation and in EuroNCAP and of reparability tests have led to safer vehicle for their occupants, but also to more aggressive vehicles in car to car impacts [1].

Two main types of incompatibility have been put forward: stiffness and geometric incompatibility [2, 3, 4, 5, 6, 7, 8]. Stiffness compatibility include all the problems due to the difference of stiffness between the vehicles, and geometric incompatibility deals with the problems of interaction (underriding / overriding, fork effects, local penetrations, undeformed load paths...). But there are still many discussions on these topics because phenomena that happen in car to car crashes are difficult to understand: how do vehicles interact? Which role plays the engine? Are the force level linked to the force levels measured in offset deformable barrier (ODB) tests? ... Consequently it doesn't seem to be easy to find an adapted evaluation procedure for compatibility.

This paper presents our understanding of stiffness and geometric compatibility. It also proposes a potential solution in two steps for taking compatibility into account.

WHICH SEVERITY?

Presently vehicles are designed to behave in a certain way in self-protection tests (EEVC barrier 56 kph regulation test and EEVC barrier 64 kph EuroNCAP test). Consequently they are designed for a crash severity up to an equivalent energy speed (EES) of about 56 kph. Beyond this EES the protection offered by the vehicle is not known.

Theoretically in car to car crash it is consequently expected to offer the same protection up to a closing speed of 112 kph. But this only works if there is an ideal compatibility between the cars, which means perfect energy absorption and perfect matching of the force levels. In order to add a security margin a good protection can only be ensured up to a closing speed of 100 kph.

STIFFNESS COMPATIBILITY

One of the risks in car to car crashes is that one of the cars is submitted to higher forces than those it is designed for (figure 1).

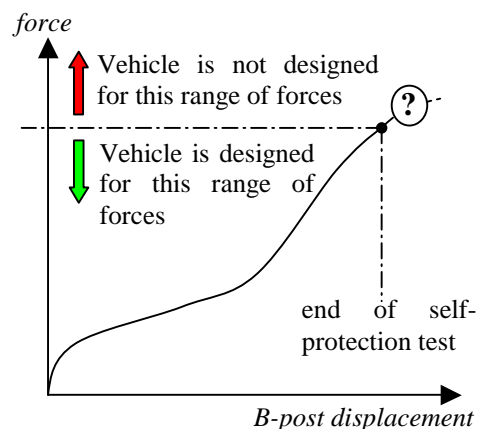


Figure 1. Example of deformation characteristic

The most common idea consists in making sure that front-end forces are below passenger compartment resistances (figure 2).

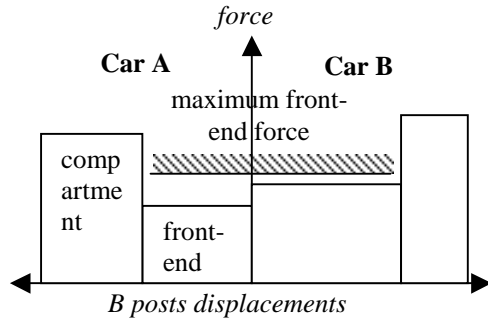


Figure 2. Proposed force management

But although this concept of force management (also called ‘bulkhead concept’ [9, 10]) is theoretically acceptable, it is practically very difficult to apply for many reasons.

- The first reason is that compartment resistance is very difficult to evaluate. In most of the cars the maximum compartment resistance is reached at a speed higher than 64 kph. So that a test at a higher speed might be needed to assess this resistance. 80 kph tests have been proposed [11]. Figure 3 shows an example of these two tests. 80 kph tests might be convenient for some cars, but it seems that there is a risk of non-repeatability if we go too far beyond the limit. The consequence is that to assess the maximum resistance of compartments, an adapted test speed would be needed for each car. It should be high enough to reach the maximum of the car, but not too high for repeatability reason. The conclusion is that it is not possible to assess compartment resistance with a rating or a compliance procedure.

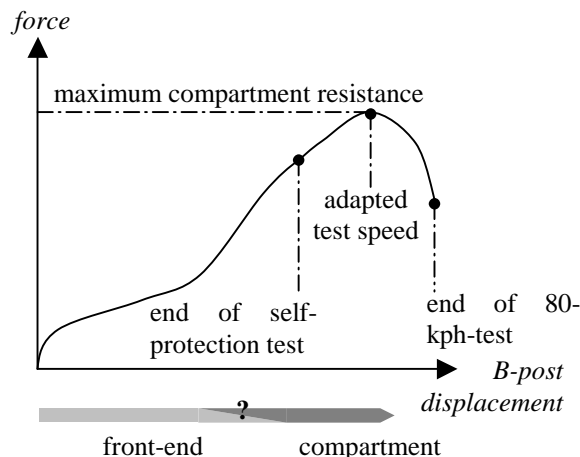


Figure 3. Tests for the assessment of maximum compartment resistance

- The second reason is that the frontier between front-end and passenger compartment is not well known

(see figure 3). As long as we are not able to define this frontier it is not possible to define a front-end force.

A solution can be proposed for these two points. With an EES of 56 kph we know that compartment is already deforming. So that we can propose a minimum force in the self-protection test to make sure that each compartment resistance is beyond this common level without an extra test at a higher speed. But we must also make sure that high force levels are not reached too early. For an EES of about 50 kph (approximately when the area under the force – deflexion curve is 90% of the total area, in the 64 kph self-protection test) we can propose a maximum force in order to provide a certain level of force matching in the car to car test and also to limit front-end forces. It is also interesting to put these two force levels on the same test because this ensures that they are therefore comparable (forces derived from the same tool). Figure 4 presents this concept.

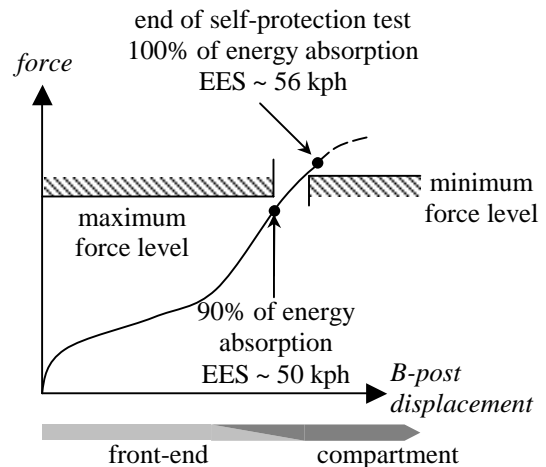


Figure 4. Potential solution for force management

But there are two more reasons that compromise this force management:

- The third reason is the mechanical peak. In a force measurement there is a part that is due to the impact of rigid mechanical parts (figure 5). This impact depends on the type of test, and is not representative of what happens in car to car crashes. We need a better understanding of the compatibility phenomena; particularly the role of the engine, to be able to make predictions based on barrier test force measurements.

- The fourth reason is that in most of the crashes that have been done, the problem of interaction between the cars was the main problem. This leads us to the problem of geometric compatibility.

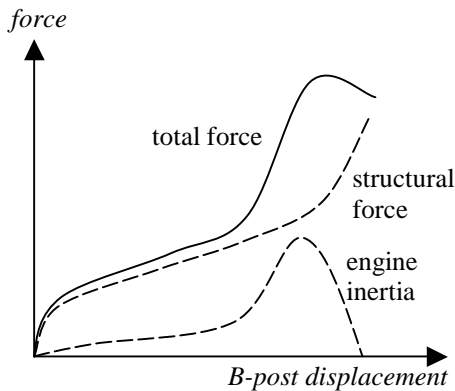


Figure 5. Inertia effects in force measurements

GEOMETRIC COMPATIBILITY

The other main risk in car to car crashes is that one of the cars is submitted to a type of load it is not designed for due to geometric incompatibility. A problem of interaction is able to ruin all the prediction based on stiffness:

- Compared with the prediction (figure 6), a lack of energy absorption in the front-ends, due to bad interaction, results in too high forces on the compartments of the cars. This leads to higher compartment deformation (figure 7).
- A bad interaction also results in local forces applied on the opponent. For instance a longitudinal that doesn't collapse in a car to car crash can impact directly the A-pillar or the bulkhead of its opponent.

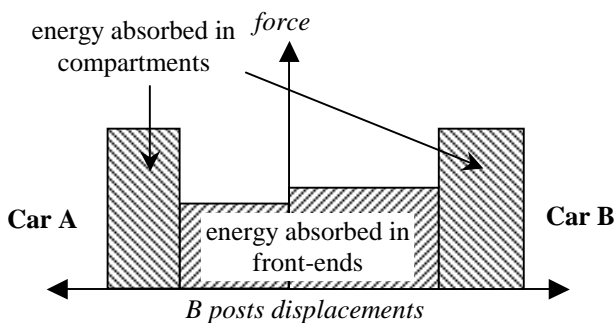


Figure 6. Prediction of energy absorption in the cars

This led most of the groups working on compatibility to the conclusion that structural interaction is a prerequisite for compatibility [7].

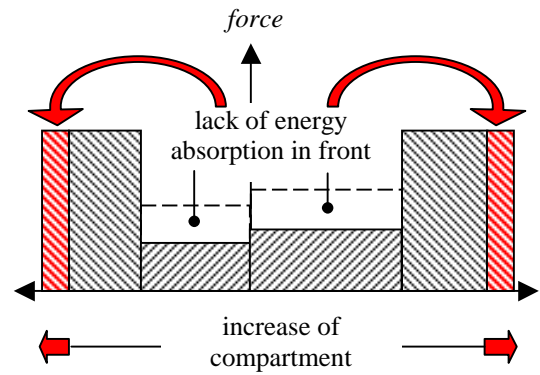


Figure 7: Consequence of bad energy absorption in the front-ends

Two ways to achieve good structural interaction have been proposed:

- The first one is to have a homogeneous distribution of stiffness of the front end [5]. But this does not seem to be realistic due to the presence of the engine and the limited number of load paths.
- The second one is to have strong connections between load paths in order to create a kind of mesh between the vehicles and therefore increase the level of interaction [2, 3, 7, 8, 12].

For many reasons (including realism, feasibility, air cooling, reparability...) and with the support of tests (a car to car test with reinforced horizontal and vertical connections between longitudinals and subframe gave better results than the same test with unmodified cars), we believe that connections between the load paths provide a better solution to the interaction problem.

PSA'S PROPOSAL : A TWO-STEP APPROACH

As we saw previously, in compatibility some subjects are commonly understood (mainly the importance of structural interaction) while other ones still need studies and validations (like force management). This point drove us to the conclusion that a two step approach could be necessary to deal with the problem of compatibility:

A first step toward compatibility could consist in proposing two measures that go in the good direction:

- Improve geometric compatibility with a test in which the vehicle has to create a mesh and use its connections.
- Improve compartment integrity (we are sure it will improve crashworthiness) by imposing a minimum compartment force.

And then as a second step, when we have better knowledge of compatibility, and also when we will have cars which respect the first step and by assessing the results of this step, we will be able to propose a complete evaluation of compatibility including a maximum front-end force.

First step

In the first step the goal is to improve geometric compatibility and compartment integrity.

For many reasons a compatibility test shouldn't be disconnected from actual accidents (about 60% of which are offset crashes in Europe) and from self-protection test (40% offset test with EEVC barrier), so that an offset test is recommended. The characteristics of the barrier should consequently be as follows:

- Stiffer than the EEVC barrier, and with progressive stiffness like the front-ends of vehicles. This barrier should be able to create shear in order to promote connections between load paths by requiring the vehicle to create a good interaction surface with the barrier.
- Deeper than the EEVC barrier to avoid bottoming out (unrealistic contact with the rigid wall).

It seems that an ADAC [12, 13, 14] like or a PDB [3, 7] like barrier is a good compromise (figures 8 and 9), although the ADAC barrier has an unrealistic stiffness in its upper part.

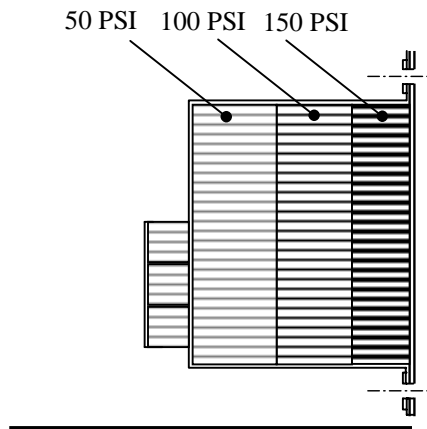


Figure 8: ADAC barrier

To evaluate geometric compatibility of the vehicle against this barrier (which represents a virtual ideal impacted vehicle), criteria on the maximum penetration, the difference between mean and maximum penetration, horizontal and vertical homogeneity of the deformation, aspect of the barrier (perforations...) should be achieved.

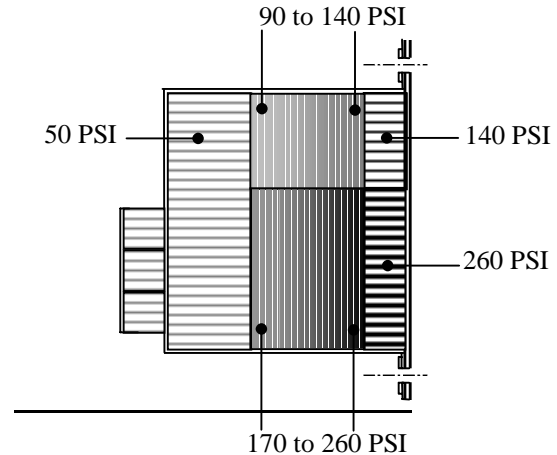


Figure 9: Progressive deformable barrier (PDB)

Ensuring compartment integrity is of double interest: it is good for compatibility and self-protection. This idea comes from the observation of car to car crashes in which incompatibility appears: in most of the cases the easiest and more effective way to prevent overcrash of one of the cars (generally the smallest one) would be to reinforce its passenger compartment. To improve compartment integrity we propose a common minimum force every vehicle is able to sustain. Imposing a minimum force level that vehicles should be able to reach in the 64-kph test can do this.

Second step

The second step depends on the results of the first step, and of our progress in the knowledge of phenomena which take place in car to car crashes.

In this second step we propose to deal with deformation. This could be done by limiting front-end force with a limit on the 64-kph-test curve as proposed above, or with another better method.

Energetic compatibility (i.e. availability of deformation energy in the cars in order to be able to ensure the same EES in both cars in the car to car test) could also be dealt with in this second step.

CONCLUSION

In order to improve safety in car-to-car crashes up to a closing velocity of 100 kph, different proposals have been proposed to deal with the problems of stiffness compatibility and geometric compatibility. But many details and phenomena are not yet understood. Consequently a total compatibility procedure is not ready to be proposed and established.

However the gap between old designs and new designs is continually growing, as well as incompatibility among

the vehicle fleet. Therefore it is important to set limits as soon as possible to the items we understand. This first step toward compatibility could consist in:

- Improving geometric compatibility with an offset test. The deformable barrier must be a specific barrier for this purpose: stiffer and deeper than the EEVC barrier, and with progressive stiffness.
- Improving compartment integrity by imposing a minimum resistance.

Later, when we have a better understanding of compatibility, and regarding the results of the first step, a second step could be proposed. This second step could deal with front-end force, energy management...

REFERENCES

1. F.Zeidler, F.Knöchelmann "The influence of frontal crash test speeds on the compatibility of passenger cars in real world accidents", IJCrash 1998 Vol 3 No 1

2. C.Steyer, M.Delhommeau, P.Delannoy "Renault's proposal to improve compatibility in head on collision", ESV 1998, Windsor

3. C.Steyer, A.Diboine, M.Delhommeau, P.Delannoy "Taking compatibility aspects into account when designing vehicles", VDA Technical Congress 1999, Frankfurt

4. F.Zeidler, F.Knöchelmann, D.Scheunert "Possibilities and limits in the design of compatible cars for real world accidents", SAE 1999-01-0068

5. N.J.Wykes, M.J.Edwards, C.A.Hobbs "Compatibility requirements for cars in frontal and side impact", ESV 1998, Windsor

6. E.Faerber "Crash Kompatibilität in Pkw – Pkw Unfällen", Crash Tech 2000, Munich

7. EUCAR compatibility group "Development of criteria and standards for vehicle compatibility", contract BRPR-CT97-0589 – project BE97-4049

8. PREDIT compatibility group "Compatibilité"

9 R.Zobel "Accident analysis and measures to establish compatibility", SAE 1999-01-0065

10. R.Zobel "Demands for compatibility of passenger vehicles", ESV 1998, Windsor

11. C.A.Hobbs "Compatibility – the essential requirements for cars in frontal impact", Vehicle Safety 2000, London

12. "Investigation of the test speed, compatibility and aggressivity of cars", report on the crash test programme 1997 – 98, contract n° B3-B96-B2 7020-SIN 3523.

13. W.Klanner, B.Felsch, F.van West "Evaluation of occupant protection and compatibility out of frontal crash tests against the deformable barrier", ESV 1998, Windsor

14. W.Klanner, K.Langwieder "The correlation between test and real-life accidents for the car-to-car frontal crash" ESV 1996, Melbourne